GP 3600 12/6/00 Request for Reconsideration #18

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	:	Docket No.: OT-4328
Frank W. Adams, et al.	:	Date: November 17, 2000
Serial No.: 09/163,259	:	Group No.: 3652
Filed: September 29, 1998	:	Examiner: S. McAllister

Title: ELEVATOR SYSTEM HAVING DRIVE MOTOR LOCATED BETWEEN ELEVATOR CAR AND HOISTWAY SIDEWALL

Director of Patents and Trademarks
Washington, D.C. 20231

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Director of Patients and Trademarks, Washington, D.C. 20231 on

[signature]
Signature
11-17-00
Date

REQUEST FOR RECONSIDERATION

Dear Sir:

This is a request for reconsideration of the Office Action mailed August 18, 2000. Claims 1-6, 8 and 19 were rejected in the Office Action.

Claims 1 and 19 were rejected as being unpatentable over Aulanko et al. (EP0710618) in view of Pearson (1035230). According to the Office Action, it would have been obvious to modify the apparatus of Aulanko et al. to use the flat ropes disclosed in Pearson in order to produce a large friction surface.

NO MOTIVATION

Applicants respectfully disagree with this rejection. There is no motivation to combine these two references. The motivation cited in the Office Action to justify this combination is to produce a large friction surface. There is no indication within Aulanko et al. that additional friction surface would be desirable and, indeed, in elevator applications, too much friction is a safety hazard. In the event of an overrun of the elevator car, slip between the ropes and the traction sheave is necessary to avoid pulling the car into the roof of the building. This is particularly true for cars that utilize underslung roping.

DESTROY FUNCTION

Next, and more importantly, the use of flat ropes as disclosed in Pearson with the apparatus of Aulanko et al. would destroy the function and purpose of the invention of Aulanko et al. As stated in the specification (column 1, line 49 to column 2, line 26), the principle objective is a space saving elevator. This is accomplished by using a flat machine

unit such that the cross-sectional area of the hoistway is minimized. Using flat ropes, however, requires a traction sheave having an expanded axial dimension to account for the flattening out of the ropes. For the machine of Aulanko et al., this means that the traction sheave (item 7) would need to be extended and therefore the flatness of the machine would be eliminated. As a result, the space required for the machine is expanded and the objective of minimizing cross-sectional hoistway space is destroyed.

ARE NOT USED

Finally, flat, steel straps, such as those suggested in Pearson, are not used in elevator systems for several reasons. First, the straps are cross-sectionally continuous and thus have an effective modulus of elasticity that corresponds to that of steel, i.e., $\sim 30 \times 10^6$. Materials having this level of flexibility need to be formed very thin in order to be flexible enough to bend around a sheave repeatedly, as is required of elevator ropes. In elevator ropes, this problem is solved by making the rope from a plurality of thin wires. Each wire is very flexible due to its small diameter and as a result the rope is flexible. The strength of the rope, however, is the sum of the load carrying capacity of the individual wires. Therefore, the flexibility of the rope is enhanced by the use of multiple thin wires without a loss of strength. In effect, the effective modulus of elasticity for a wound wire rope is a fraction of the actual modulus of elasticity of the rope material. This is evidenced in Enclosure #1 and #2, which are representative wire rope properties. Enclosure #1 is taken from a manufacturer's wire rope engineering handbook and indicates that for conventional elevator wound wire ropes (identified by the classification "6x "X" IWRC", where the "X" can vary), the modulus of elasticity is approximately $\sim 12\text{-}13 \times 10^6$. This value is also confirmed in Enclosure #2, which is taken from a rope supplier. This means that the modulus of elasticity for steel straps is on the order of 2-3 times that of wound wire ropes. The result is that for a conventional elevator system to use a steel strap as a lifting rope, assuming the steel strap could be made as thin as the wires of a conventional wound wire rope, the diameter of the sheaves would need to be multiplied by the ratio of modulus of elasticity for steel and the effective modulus of elasticity of a comparable wire rope. Unfortunately, this would result in a very large sheave and very large torque requirements for the drive machine, since the elevator loads and the tension in the ropes is constant. In addition, to support the tensile loads, such a thin strap would need to be inordinately wide. Therefore, one skilled in the art would not consider using flat, steel straps as an elevator rope.

Second, the use of flat straps formed from a continuous material would introduce significant safety issues. Elevator ropes are subject to significant wear and environmental factors. For instance, wear caused by differential motion between the rope and sheave leads to cracks and fractures in the individual wires of the rope. Exposure to moisture leads to rust and pitting of the rope material. In addition, there may be surface imperfections produced during the manufacture of the rope material. Since elevator ropes are under constant tension and repeated flexure, these cracks and fracture propagate through the material. For wound wire ropes, the failure of an individual wire is self-mitigating. Each wire is interwoven with other wires and other strands such that even individual wires with breaks along their length are still useful to carry tension loads (see Enclosure #3 for support for this statement).

For flat straps formed from a continuous material, however, any cracks or fractures would propagate through the strap and result in a catastrophic failure of the rope. This failure mode is unacceptable in elevator ropes. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

Third, wound wire ropes take advantage of the additional flexibility provided by the helical wrapping of the strands and cords within the rope. Such helical wrapping permits the wires and strands to move relative to each other to accommodate the differential lengths that the rope is subject to as it travels over a sheave. A steel strap, since it is continuous, cannot accommodate this effect and results in high tensile stress on one side of the strap and high compressive stress on the opposite side of the strap. These repetitive stresses lead to fatigue and cracking of the strap, which, as discussed above, would propagate through the strap and lead to a catastrophic failure. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

Fourth, elevator ropes are exposed to and required to operate in a harsh environment. Moisture and other contaminants cause rust and pitting of the rope material. For wound wire ropes, lubrication is used to provide a surface protectant to the wires. For flat straps, however, lubrication would degrade the traction between the strap surface and the sheave. As a result, either the traction between the sheave and strap would be insufficient or, if no lubricant is used, the strap would be subject to significant environmental degradation, which, as discussed above, would result in catastrophic failure of the strap. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

Fifth, elevator ropes have a range of traction within which they must operate. If the traction is too low, there is slip during normal operation. For wound wire ropes, environmental contaminants on the rope can be accommodated because of the configuration of the ropes. Traction is produced by the interaction of the crown of the wires and strands with the surface of the sheave, while the spaces between wires and strands can accept the environmental contaminants. For smooth flat straps, however, there are no spaces for the contaminants and this can lead to a dramatic reduction in traction. For instance, moisture on the straps or sheave can result in a film of water that produces a hydrodynamic effect and essentially reduces the traction to zero.

If the traction is too high, there is no slip and there is a risk that the car or counterweight may not break traction when the car or counterweight is at the top of the hoistway. Without slip in this instance, the car or counterweight could be pulled into the overhead of the hoistway. In conventional ropes, an appropriate range of traction is achieved by lubricating the ropes to prevent too much traction, which can occur with dry metal-to-metal contact. For steel straps, however, as discussed above lubrication cannot be used. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

The conclusion then, is that there are significant limitations with using flat straps formed from a cross-sectionally continuous material and those limitations explain why elevator systems do not use such configurations as ropes. This fact is well known to those skilled in the art and such persons, upon receiving a suggestion to use flat steel straps, would immediately disregard the suggestion as **impractical, unsafe and inoperable** in elevator systems. Therefore, one skilled in the art of elevator systems would not consider combining the flat straps suggested in Pearson as elevator ropes with any other elevator system, let alone the combination suggested in this rejection.

Therefore, the combination of Aulanko et al. and Pearson is improper and this rejection of Claims 1 and 19 is traversed. Applicants respectfully request reconsideration and allowance of Claims 1 and 19.

Claims 2-6 and 8 were rejected as being unpatentable over Aulanko et al. (EP 0710618) in view of Pearson, and further in view of Olsen. According to the Office Action, the motivation for this combination is to facilitate the use of the columns to guide both the car and counterweight.

Applicants respectfully disagree with this rejection. First, as discussed above, the combination of Aulanko et al. and Pearson is improper. Therefore, the combination of Aulanko et al., Pearson and Olsen is also improper.

HINDSIGHT.

Second, this combination is a clear case of hindsight reconstruction. Aulanko et al. discloses a system having a single set of traction ropes and using separate guide rails for the car and counterweight, with the counterweight rails supporting the machine. Pearson discloses using flat steel straps. Olsen discloses a system having one set of rails for guiding both the car and counterweight with the machine supported by the hoistway wall. This rejection, however, combines the basic system of Aulanko et al. with the flat ropes of Pearson by assuming that such ropes could be used to suspend the car and counterweight, and then further combines Aulanko et al. with the guide rails of Olsen by assuming that the guide rails of Aulanko et al. could be modified to guide both the car and counterweight and still support the machine. In effect, this rejection picks and chooses specific features of dramatically different systems, and ignores the differences between the systems, to produce the claimed invention.

Therefore, the combination of Aulanko et al. with Pearson and Olsen is improper and this rejection of Claims 2-6 and 8 is traversed. Applicants respectfully request reconsideration and allowance of Claims 2-6 and 8.

OOPS

Claim 19 was rejected as being unpatentable over Pearson (1,035,230) in view of Aulanko et al. (EP 0 710 618).

Applicants respectfully disagree with this rejection of Claim 19. First, there is no explanation in the Office Action of how or why these references could or would be combined. Second, for the reasons discussed above, this combination of references cannot be combined without destroying the function and objective of one of the references. Finally, any combination of references requiring the use of steel straps as taught by Pearson is impractical, unsafe and inoperable.

Therefore, this rejection of Claim 19 is traversed and Applicants respectfully request reconsideration and allowance of Claim 19.

Inasmuch as neither the structure nor function of Applicants' invention has been anticipated or made obvious, Applicants respectfully request reconsideration and allowance of pending Claims 1-6, 8 and 19.

Please charge any additional fees or credit overpayment to Deposit Account No. 15-0750, Order No. OT-4328.

Respectfully submitted,

FRANK W. ADAMS, et al.

Randy G. Henley
Registration No. 33,188

Otis Elevator Company
Intellectual Property Department
10 Farm Springs
Farmington, CT 06032
(860) 676-5742

Stretch of Wire Rope

Approximate Moduli of Elasticity

The modulus of elasticity of a wire rope varies throughout its life and is dependent on the construction of the rope and the conditions under which it operates. This modulus increases during the useful life of the rope. It is affected by the length of service of the rope, the intensity of working loads, whether these loads are constant or variable, and the amount of bending and vibration to which the rope is subjected.

The commonly used approximate values for moduli of elasticity of the various constructions are listed below.

New or unused wire ropes will have a greater elongation than used ropes, because the greater portion of the structural stretch of a rope occurs during the initial period of its useful life. The modulus of elasticity is also the smallest during this period.

Construction		Approximate Modulus of Elasticity
6x7 Fiber Core		12,000,000
6x7 IWRC		14,000,000
6x17 IWRC 6x19 Seale IWRC 6x21 FW IWRC 6x25 FW IWRC		13,000,000
6x19 Fiber Core 6x30, Type G Fiber Core		12,000,000
6x37 Fiber Core		11,000,000
6x37 IWRC		12,000,000
8x19 Fiber Core		10,000,000
Galvanized Wire Core Bridge Ropes	6x7	16,000,000
	6x19	15,000,000
	6x37	14,000,000
Prestressed Galvanized Wire Core Bridge Ropes		20,000,000
Galvanized Bridge Strands Galvanized Guy Strands	7 Wire	21,000,000
	19 Wire	19,000,000
	37 Wire	18,000,000
	61 Wire	17,000,000
	91 Wire	16,000,000
Prestressed Galvanized Bridge Strands		24,000,000 up to 2 9/16 23,000,000 2 5/8 & Larger
Locked Coil Track Strand		19,000,000
Smooth Coil Track Strand		19,000,000
3x7 Torque Balanced Super Tensile Elevated Elastic Limit		20,500,000
3x19 Torque Balanced Super Tensile Elevated Elastic Limit		20,500,000
3x36 Torque Balanced Super Tensile Elevated Elastic Limit		20,000,000
3x46 Torque Balanced Super Tensile Elevated Elastic Limit		20,000,000
3x55 Torque Balanced Super Tensile Elevated Elastic Limit		20,000,000
6x25 Super Tensile Unit Lay IWRC		16,000,000
6x36 Super Tensile Unit Lay IWRC		16,000,000

The moduli of elasticity shown on this page are for wire ropes and strands of standard constructions and with standard lengths of lay.

ELASTIC STRETCH

Elastic stretch results from recoverable deformation of the metal itself. Here, again, a quantity cannot be precisely calculated. However, the following equation can provide a reasonable approximation for a good many situations.

$$\text{Changes in length (ft.)} = \frac{\text{Change in load (lb)} \times \text{Length (ft)}}{\text{Area (inches}^2\text{)} \times \text{Modulus of Elasticity (psi)}}$$

The modulus of elasticity is given in Table 17, and the area can be found in Table 18.

TABLE 17 APPROXIMATE MODULUS OF ELASTICITY*

(pounds per square inch)

Rope Classification	Zero through 20% Loading	21% to 65% Loading
6 x 7 with fiber core	11,700,000	13,000,000
6 x 19 with fiber core	10,800,000	12,000,000
6 x 37 with fiber core	9,900,000	11,000,000
8 x 19 with fiber core	8,100,000	9,000,000
6 x 19 with IWRC	13,500,000	15,000,000
6 x 37 with IWRC	12,600,000	14,000,000

*Applicable to new rope with constructional stretch removed.

EXAMPLE: How much *elastic stretch* may occur in 200 ft of 1/2 inch 6 x 25 FW IPS FC rope when loaded to 20% of its nominal strength:

Nominal strength = 10.7 tons (21,400 lb)
20% of which = 4,280 lb.

Area of 1/2 inch is found by squaring the diameter and multiplying it by the area of 1 inch rope given in Table 18 under the "Fiber Core" heading and opposite 6 x 25 FW, i.e., 1/2 x 1/2 x .417=.104.

The modulus of elasticity is found in Table 17 opposite the 6 x 19 fiber core (because 6 x 25FW is a member of this class) and under the "Zero through 20% Loading."

Substituting these values, the equation reads as follows:

$$\text{Change in length} = \frac{4280 \times 200}{.104 \times 10{,}800{,}000} = .76 \text{ Ft (9.1 inches)}$$

A word of caution concerning the use of Table 17: the higher modulus given under the "21% to 65% Loading" is based on the assumption that both the initial and the final load fall within this range. If the above example were restated to the effect that the load was 35% (or 7,490 lb) of the nominal strength, it would be incorrect to rework the problem simply by making two substitutions: the new load and the higher modulus of 12,000,000 psi. To do so would ignore the greater stretch that occurs at the lower modulus during the initial loading.

TELEFAX-

MESSAGE Nr. No. 72/91

Von: From:
DRAKO
Drahtseilerei Gustav Kocks GmbH
Muehlenberg 20 / PB. 100451
4330 Muelheim/Ruhr 1
West-Germany
Telefon: (0208) 42901-0
Telex: 856872 drako d
Telefax: (0208) 4290143

an: to: Bob Gill

Datum: Date: February 7th, 1991

Fa.: Co.: AFD, USA

Bearbeiter: In charge: Dr. Michael Molkow/sk

Fax Nr.: No.:

Abt.: depart.:

Tel.-Durchw. extension -48

Betr./Subject: Your fax no. 4888 dt. February 2nd, 1991

1/2" DRAKO 300 T = Full steel rope (IWRC)

E-Modulas are not dependent on a diameter in certain limits, they are only dependent on the rope construction, condition of the rope and load-range .

1 N/mm² = 145.04 psi

E-Modulus:

New rope: ca. 80000 N/mm² = 11,603,200 psi

Rope in use for at least 1 months: 90000 - 100000 N/mm² = 13,053,600 / 14,504,000 psi

But: in reality a rope has no Elast. Modulus. It is only a matter of agreement, in what range of load you can calculate with f.i. the above mentioned figures. Here we speak of elevator-loads, and that means 50 to 150 N/mm².

With kind regards
DRAHTSEILEREI GUSTAV KOCKS
G M B H

signed Dr. Molkow

Flat, steel straps, such as those suggested in Pearson or DE '120, are not used in elevator systems for several reasons. First, the straps are cross-sectionally continuous and thus have an effective modulus of elasticity that corresponds to that of steel, i.e., ~$30x10^6$. Materials having this level of flexibility need to be formed very thin in order to be flexible enough to bend around a sheave repeatedly, as is required of elevator ropes. In elevator ropes, this problem is solved by making the rope from a plurality of thin wires. Each wire is very flexible due to its small diameter and as a result the rope is flexible. The strength of the rope, however, is the sum of the load carrying capacity of the individual wires. Therefore, the flexibility of the rope is enhanced by the use of multiple thin wires without a loss of strength. In effect, the effective modulus of elasticity for a wound wire rope is a fraction of the actual modulus of elasticity of the rope material. This is evidenced in Enclosure #1 and #2, which are representative wire rope properties. Enclosure #1 is taken from a manufacturer's wire rope engineering handbook and indicates that for conventional elevator wound wire ropes (identified by the classification "6x "X" IWRC", where the "X" can vary), the modulus of elasticity is approximately ~$12\text{-}13x10^6$. This value is also confirmed in Enclosure #2, which is taken from a rope supplier. This means that the modulus of elasticity for steel straps is on the order of 2-3 times that of wound wire ropes. The result is that for a conventional elevator system to use a steel strap as a lifting rope, assuming the steel strap could be made as thin as the wires of a conventional wound wire rope, the diameter of the sheaves would need to be multiplied by the ratio of modulus of elasticity for steel and the effective modulus of elasticity of a comparable wire rope. Unfortunately, this would result in a very large sheave and very large torque requirements for the drive machine, since the elevator loads and the tension in the ropes is constant. In addition, to support the tensile loads, such a thin strap would need to be inordinately wide. Therefore, one skilled in the art would not consider using flat, steel straps as an elevator rope.

Second, the use of flat straps formed from a continuous material would introduce significant safety issues. Elevator ropes are subject to significant wear and environmental factors. For instance, wear caused by differential motion between the rope and sheave leads to cracks and fractures in the individual wires of the rope. Exposure to moisture leads to rust and pitting of the rope material. In addition, there may be surface

imperfections produced during the manufacture of the rope material. Since elevator ropes are under constant tension and repeated flexure, these cracks and fracture propagate through the material. For wound wire ropes, the failure of an individual wire is self-mitigating. Each wire is interwoven with other wires and other strands such that even individual wires with breaks along their length are still useful to carry tension loads (see Enclosure #3 for support for this statement).

For flat straps formed from a continuous material, however, any cracks or fractures would propagate through the strap and result in a catastrophic failure of the rope. This failure mode is unacceptable in elevator ropes. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

Third, wound wire ropes take advantage of the additional flexibility provided by the helical wrapping of the strands and cords within the rope. Such helical wrapping permits the wires and strands to move relative to each other to accommodate the differential lengths that the rope is subject to as it travels over a sheave. A steel strap, since it is continuous, cannot accommodate this effect and results in high tensile stress on one side of the strap and high compressive stress on the opposite side of the strap. These repetitive stresses lead to fatigue and cracking of the strap, which, as discussed above, would propagate through the strap and lead to a catastrophic failure. Therefore, one skilled in the art would not consider using flat straps made o steel as an elevator rope.

Fourth, elevator ropes are exposed to and required to operate in a harsh environment. Moisture and other contaminants cause rust and pitting of the rope material. For wound wire ropes, lubrication is used to provide a surface protectant to the wires. For flat straps, however, lubrication would degrade the traction between the strap surface and the sheave. As a result, either the traction between the sheave and strap would be insufficient or, if no lubricant is used, the strap would be subject to significant environmental degradation, which, as discussed above, would result in catastrophic failure of the strap. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

Fifth, elevator ropes have a range of traction within which they must operate. If the traction is too low, there is slip during normal operation. For wound wire ropes, environmental contaminants on the rope can be accommodated because of the

configuration of the ropes. Traction is produced by the interaction of the crown of the wires and strands with the surface of the sheave, while the spaces between wires and strands can accept the environmental contaminants. For smooth flat straps, however, there are no spaces for the contaminants and this can lead to a dramatic reduction in traction. For instance, moisture on the straps or sheave can result in a film of water that produces a hydrodynamic effect and essentially reduces the traction to zero.

If the traction is too high, there is no slip and there is a risk that the car or counterweight may not break traction when the car or counterweight is at the top of the hoistway. Without slip in this instance, the car or counterweight could be pulled into the overhead of the hoistway. In conventional ropes, an appropriate range of traction is achieved by lubricating the ropes to prevent too much traction, which can occur with dry metal-to-metal contact. For steel straps, however, as discussed above lubrication cannot be used. Therefore, one skilled in the art would not consider using flat straps made of steel as an elevator rope.

The conclusion then, is that there are significant limitations with using flat straps formed from a cross-sectionally continuous material and those limitations explain why elevator systems do not use such configurations as ropes. This fact is well known to those skilled in the art and such persons, upon receiving a suggestion to use flat steel straps, would immediately disregard the suggestion as **impractical, unsafe and inoperable** in elevator systems. Therefore, one skilled in the art of elevator systems would not consider combining the flat straps suggested in Pearson or DE '120 as elevator ropes with any other elevator system, let alone the combination suggested in this rejection.

Enclosure #1: USS Tiger Brand Wire Rope Engineering Handbook

Enclosure #2: Telefax from Dr. Molkow, DRAKO

Enclosure #3: "Elevator Wire Ropes; Why wire ropes", Elevator World, March 1994

Mary — Will this help Kitty

ELEVATOR WIRE ROPES

Why Wire Ropes?

Part 1 – From Factory to Field

Dr.-Ing. Michael Molkow graduated in 1963 as a Diplom-Ing. (Machinery) from the Technische Hoch Schule in Stuttgart and remained at the Wire Rope Research Institute of the University until 1981. He earned his Doctorate in 1982, the thesis being "Traction Capacity of Drive Sheaves with Hardened U-Grooves," and joined Drahtseilerei Gustav Kocks (Drako) in 1988 as Technical Director.

In the 100 years electric elevators have been in existence, nothing better than steel wire ropes has been found. Hundreds of thousands of elevators throughout the world are driven by steel wire ropes, whether together with a traction sheave, or with a winding drum, or as transmission ropes in an indirect hydraulic elevator.

Advantages

The advantages of steel wire rope include: a) its redundancy, and b) the possibility of determining with the naked eye the degree of fatigue in running ropes. Redundancy means the parallel operation of many individual elements (wires) so that even after the breakage of some of these elements, the assembly as a whole (the rope) can remain in operation. Man made fiber ropes would also have this redundancy, steel strips and chains would not.

Fatigue occurs in ropes being bent over sheaves, through a combination of pressure and bending, tensile and torsional stress. Additionally, the rope is subjected to wear and corrosion.

Fatigue increases the number of external wire breaks, making it possible to estimate the safe service life remaining, provided the rope has been constructed correctly and the system built according to a certain set of rules. With running ropes made of fibers, abrasion and a reduction of the rope diameter would become visible with increasing time of service, but neither of these factors is useful in assessing the remaining service life.

Steel Wire Rope Composition: Wire Shape

Why are wires in the rope wound helically (see Figure 1)? A bundle of

Continued overleaf

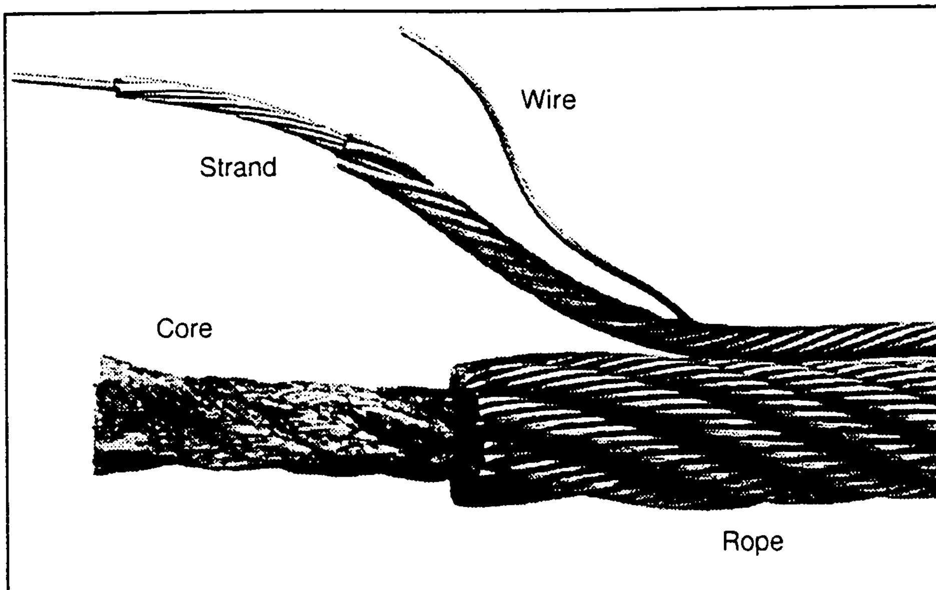

Figure 1: Components of a rope (single layer round strand rope)

parallel wires, held together by a plastic sheath, for instance, would probably have a much greater breaking force, but as soon as such a bundle of wires is bent over a sheave, the disadvantage becomes apparent, as shown in Figure 2.

The wires closest to the sheave are too long, the external wires are then too short: the bundle would fail immediately. A wire rope behaves differently, as shown in Figure 3.

When the rope moves over the sheave, sections of each strand, which are too long or too short, are very close together, so the strands need only to shift slightly to compensate. The same is true of individual wires in the strands. Consequently, the parts of a rope running over a sheave move against one another in the rope: each strand against the next, each wire against the next.

The Steel Wire

The material is a nearly plain carbon steel, with between 0.4 - 0.8% carbon, and a little bit of silicon and manganese. The high wire tensile grades possible are results of the manufacturing process: the wire is drawn (the complete process also includes additional heat treatment), and the 5- to 10-mm rolled wire rod is gradually reduced in diameter by being repeatedly drawn through dies in a cold state. At the same time, according to the reduction in diameter, its tensile grade increases between three and six times.

The relatively high tensile grade of steel wires is not a result of high alloying constituents, but of transforming the cold material, as shown in Figures 4 and 5.

As heat causes this forced structure to change, the wire material returns to its original low grade (approximately 400 N/mm^2). Ropes must, therefore, be protected from the effect of heat, from fire, friction, thermal radiation or electric arc welding, etc. Whereas it takes 15 to 30 minutes at 480°C (900°F) for the wire to retransform, even seconds at higher temperatures can be enough to damage thin wires, such as those used in elevator ropes.

Nominal Tensile Grade of Wires

Together with compensating ropes (balance or tail ropes) in shafts of mining industry hoists, elevator ropes are those produced with the lowest nominal tensile grades. Ropes with higher nominal tensile grades, such as 1770 and occasionally even 1960 N/mm^2, are used for high-rise elevators with great lengths of rope. Drum elevators and indirect hydraulic elevators also are in operation, using ropes with a nominal tensile grade of 1770 N/mm^2.

A number of nominal tensile grades of wire, which are common for ropes in the elevator industry, are shown in Tables 1 and 2.

As dual tensile ropes are not common in every part of the world, an explanation is necessary. Certain ropes have wires with one nominal tensile grade; the outer wires in other ropes have a lower tensile grade than inner wires. The latter are called "dual tensile" ropes.[1]

Numerous major elevator manufacturers have incorporated ISO Standard 4344 into their work standards.[1] A European Standard for lift ropes is due, and will probably standardize ropes numbered 5, 8, 12 and 14, mentioned in Tables 1 and 2.

A warning regarding the lowest levels of tensile grade, i.e., iron ropes and ropes with wires of 1180 N/mm^2, may be helpful. As only small quantities of such wires are required, the wire drawing mill normally does not have available the special rolled wire rod material nec-

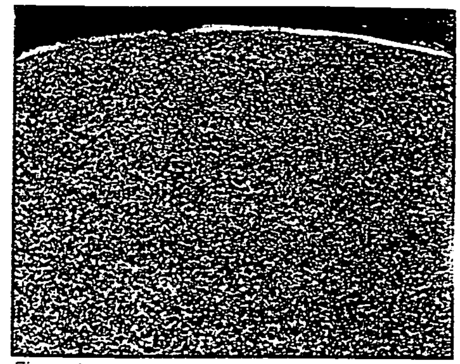

Figure 4

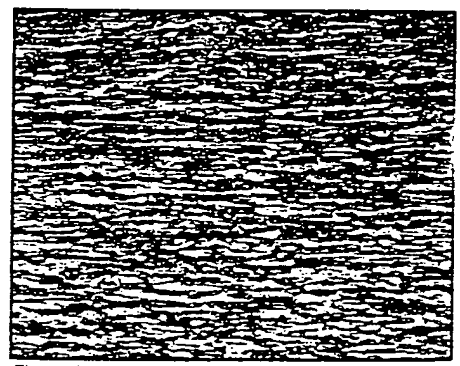

Figure 5

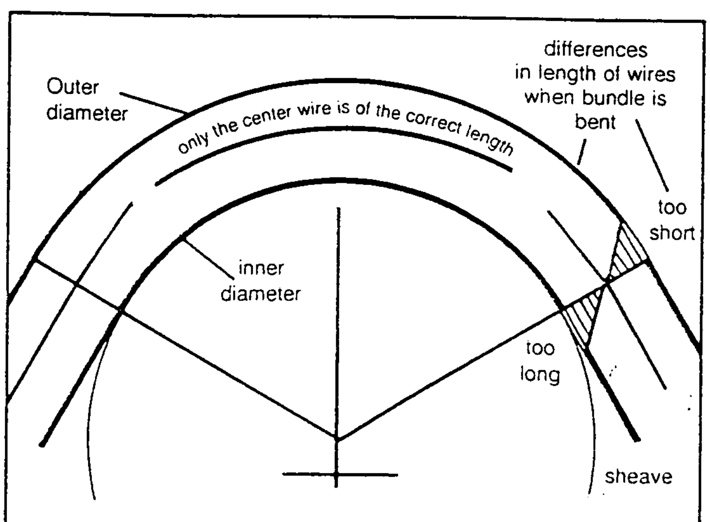

Figure 2: Parallel bundle of wires running over a sheave

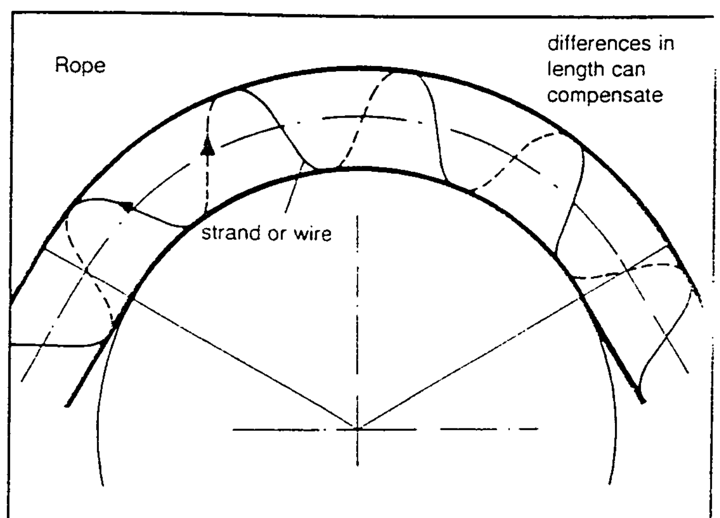

Figure 3: Wire rope running over a sheave

essary for the ideal production of such low wire grades. After all, steel is not produced in batches of one or two tons, but of hundreds of tons. As a result, such wires have more or less the required grade, but often do not have the best material structure. In this regard, a good connection between wire mill and ropery is an advantage.

"Hardness" of the Wire

Compared with the nominal tensile grades of the wires used for crane ropes, for instance, those wires used for elevator ropes are very low. In order to protect the traction sheave from wear, the hardness of the wire, which depends on the tensile grade, is kept as low as possible. Figure 6 shows the approximate relationship. It also shows that the wire is always harder than the unhardened traction sheave (Brinell hardness HB). Some elevator manufacturers require that the hardness of the wire (Vickers hardness HV) be measured and certified, but this is not necessary, as the relation between the tensile strength and the hardness of wire from any manufacturer corresponds in principle to that relationship shown in Figure 6, albeit with a certain scatter range. (Figure 6 shows the relation for non-cold-worked steel).[2]

Protecting Wires Against Corrosion

The light coat of lubricant on wires in elevator ropes is sufficient protection against corrosion for ropes used in normal elevators. If, however, the ropes are exposed to humidity (open air elevators, elevators in extremely damp surroundings), or to an aggressive atmosphere, it is advisable to use galvanized ropes. Such ropes have been used successfully in elevators for decades, but they must be galvanized ropes specially produced as elevator ropes.

Stainless steel ropes are not suitable for elevator usage. Although ropes of this material are very expensive, stainless steel cannot withstand the large number of bendings that occur in elevator systems, as can normal steel wires. The technological wire tests reveal that compared with normal steel wires, a stainless steel wire of the same diameter and tensile grade will only show 50% of the number of reverse bendings and only 5% of the number of torsions.[3]

The Strand: Strand Composition

The strand structures now in common use for elevator hoist ropes have been known for over 100

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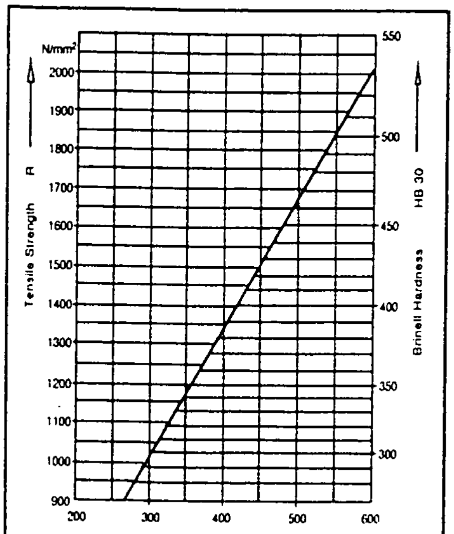

Figure 6

Consec. No.	Nominal wire tensile grade Minimum N/mm²	Wire tensile strength Maximum N/mm²	Country	National Name	Relevant standard	Application
1	690	900	USA	Iron (Iron ropes)		Governor ropes compensation ropes
2	1200	1570	USA	Traction steel		hoist ropes governor ropes
2a	1270	1480	Canada	Grade 1270	CSA G 387	hoist ropes governor ropes
3	1324	none	Japan	Grade E	JIS G-3525	hoist ropes governor ropes (?)
4	1370	1650 1670	ISO UK	Single tensile 1370	ISO 4344 BS 302, Part 4	hoist ropes governor ropes
5	1570	1870	Europe ISO UK	Single tensile 1570 " "	e.g. DIN 3051 ISO 4344 BS 302, Part 4	hoist ropes governor ropes The common rope grade in Germany.
6	1510	1730	USA	High-rise Traction steel	—	hoist ropes
7	1690	2000	USA	Extra high-grade Traction steel	—	hoist ropes for special applications
8	1720	1950	Canada	Grade 1720	CSA G 387	hoist ropes
9	1770	2050	Europe ISO	— Single tensile 1770	e.g. DIN 3051 ISO 4344	hoist ropes
10	1860	2160	Switzerland		SN 211405 ·	governor ropes
11	1960	2160	Europe	—		hoist ropes for special applications

Table 1

Consec. No.	Nominal wire tensile grade Minimum N/mm² outer/inner wires	Wire tensile strength Maximum N/mm² outer/inner wires	Country	National Name	Relevant standard	Application
12	1180/1770	1480/2070	UK	1180/1770 Dual tensile	BS 302, Part 4	hoist ropes as replacements in existing installations
13	1270/1720	1480/1950	Canada	Grade 1270/1720	CSA G 387	hoist ropes
14	1370/1770	1650/2040	Europe	Grade 1370/1770 Dual tensile	ISO 4344 BS 302, Part 4 SN 211405	hoist ropes

Table 2

 Continued from

years. They are the following:

a) Seale (Figure 7)
b) Warrington (Figure 8)
c) Filler wire (Figure 9)
d) Combination of a and b (Warrington-Seale in the form: 10+/5+5/+5+1) (Figure 10)
e) Single layer strand (6+1) wires (Figure 11)

The structures shown in a to d are multi-layer strands and are also referred to under the generic term "parallel constructions." The wires run parallel to one another, (see Figure 12), and thus are in linear contact. This avoids nicking of wires lying on top of one another and reduces wear within the strand.

Constructions of outer strands, where the wires do not run in linear contact but touch each other only at certain points, such as the strands in a 6 x 19 rope (cross lay) (see Figure 13), are not suitable for elevator ropes because of the higher incidence of wear and the danger of internal wire breaks.

Strand Geometry

When designing a strand, one must take into consideration that most of the wires in the cross section of the strand appear as ellipses. For this reason, the structure of high performance elevator ropes is designed and checked using CAD, i.e., with special computer programs. How finely graduated the wire diameters are can be seen in Figure 14 (taken from Drako elevator rope works standard).

Composition of Elevator Ropes

The simplest elevator rope can be made by closing six strands of types a to d around a fiber core (see Figure 15). Until 1955, this actually was the "normal" elevator rope. Since that time, elevators have changed drastically with regard to their speed, shaft height, frequency of use, the relationship between the weight of the car and the capacity, and in particular, with regard to demand for nearly maintenance-free systems and long service life.

Today, 8-strand ropes with natural fiber cores, mostly of Seale, but also of Warrington type, are the common elevator ropes used throughout the world (Figures 16 and 17).

In fact, this rope design (small metallic cross section plus a big fiber core) is only desirable in elevator construction, as most other rope

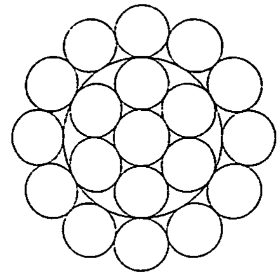

Figure 7: Cross section of a Seale-type strand (9+9+1) wires

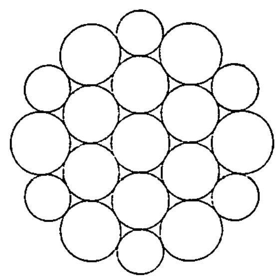

Figure 8: Cross section of a Warrington-type strand (/6+6/+6+1) wires

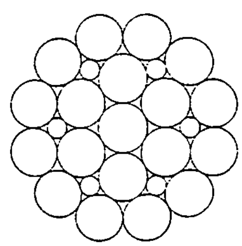

Figure 9: Cross section of a Filler wire-type strand (12+6F+6+1) wires

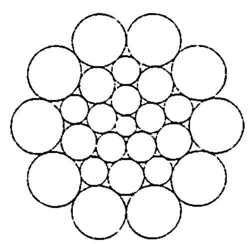

Figure 10: Cross section of a Warrington Seale-type strand (10+/5+5/+5+1) wires

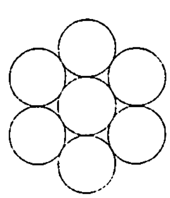

Figure 11: Cross section of a single layer strand (6+1) wires

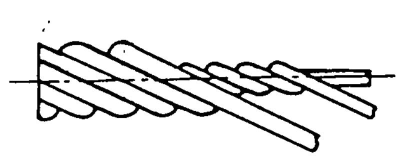

Figure 12: Position of the wires in strands of parallel construction

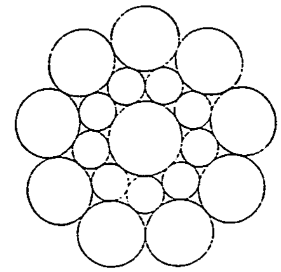

Figure 13: Cross section of a cross lay type strand (12-6+1) wires

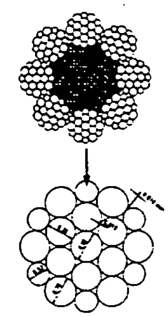

Figure 14: Geometry of a correct strand in an elevator rope nominal values of wire diameters - rope 13 mm 8x19 Warrington + fiber core

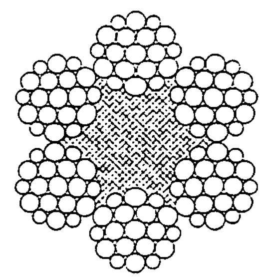

Figure 15: Rope cross section 6x19 Warrington + fiber core

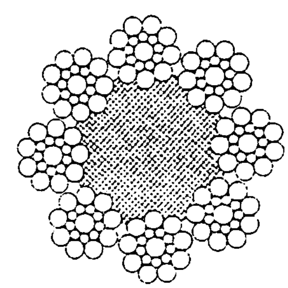

Figure 16: Rope cross section 8x19 Seale + fiber core

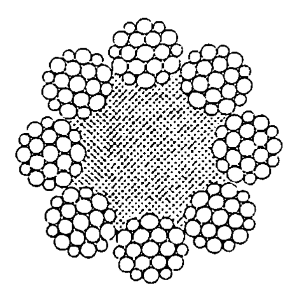

Figure 17: Rope cross section 8x19 Warrington + fiber core

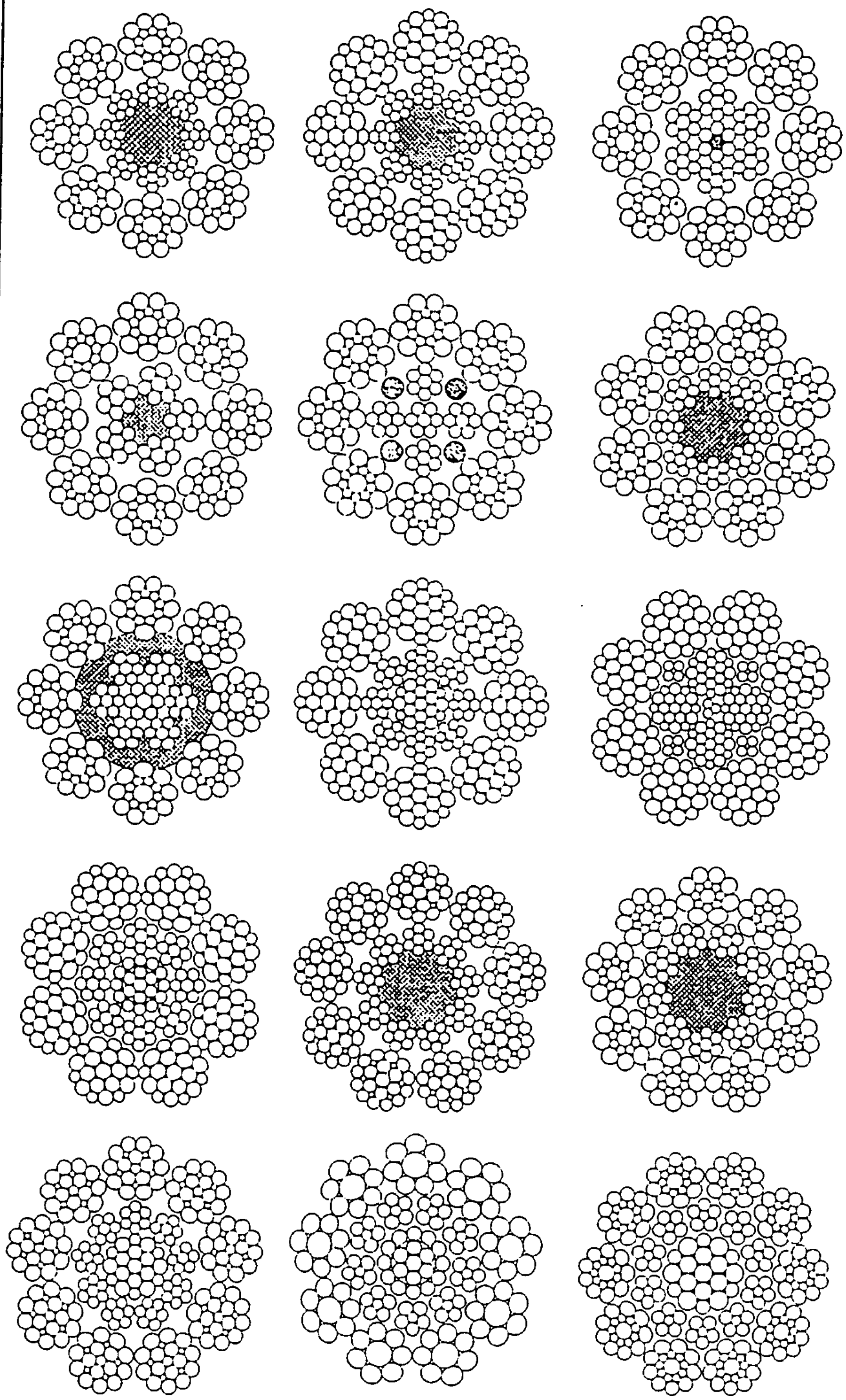

Figure 18 Overview: Rope cross sections of elevator ropes with steel cores (not comprehensive)

users require a rope with a small diameter and a high breaking load. What requirements are placed on elevator rope by legal regulations?

The following considerations show some of the connections:

a) The compulsion to limit pressure between the rope and the groove for better service life leads to a minimum requirement for the number of ropes and to a minimum demand of rope diameter. This calculation is independent of the rope's breaking force, as pressure depends on surface area of the rope, and not on the rope cross section.[4]

b) Only after this calculation should a check of the safety factor against rope breaking be made. As a result of the high safety factors for elevator ropes (relation between minimum breaking force and maximum service load), one does not require a high metallic cross section in the rope. This could encourage the choice of very few, or very thin ropes, were it not for the fact that the pressure has to be considered.

For this reason, the 8-strand rope with the fiber core, which meets the requirements of the calculation to a satisfactory degree (relatively low breaking force together with relatively large rope diameter), is widespread. Only when there are further demands on the operational behavior of the elevator rope will one ask for more suitable rope constructions, like the following:

- reduced permanent elongation;
- reduced elastic elongation;
- the rope's diameter should decrease slowly (service life is dependent on rope diameter steadiness);
- increased service life of the rope through use of thinner wires (better resistance against fatigue bendings);
- the rope should be rounder than an 8-strand rope (unfortunately, the reduction of the actual pressure, by means of an increased number of contact points between rope and groove flank, is not considered in the elevator calculations according to TRA 003 or other regulations); and
- the rope should keep its round shape (a better fit in a hardened U-groove with a wide undercut).

Many ropes with steel core offered on the market are suitable for elevators. Figure 18 gives an overview which is not comprehensive.

Most of these rope constructions are relatively new on the market,

Continued overleaf

considering the long rope service lives in elevators. A few, on the other hand, have proved successful for a long time, some for over 30 years. Figure 19 shows one of these steel core elevator ropes that has been used in Germany for many years.

It must be pointed out that for decades, Germany was the forerunner in the production and use of elevator ropes with steel cores. Some elevator manufacturers are under the impression that ropes of this kind are prohibited in their respective countries simply because the only standard for elevator ropes in force in their country is for ropes with fiber cores.

Note: Wherever ropes with steel cores are used, one should be aware that these ropes reveal their advantages, particularly in systems designed to use fiber core 8 x 19 ropes, as compared to using the same number of ropes of the same diameter, but with a steel core. Flotation-resistant ropes should not be used in traction drive elevators (see Figure 20).

As the exterior strand layer crosses over the inner layer (Figure 21), wires in these strands will nick each other, due to high pressure in the traction groove, possibly resulting in dangerous internal wire breaks going unnoticed.[7]

Why the Variety of Elevator Rope Constructions?

The layman presumes there has to be "the ideal elevator rope." However, in a traction drive elevator, a rope suffers from bending (over the sheaves) and wear (slippage on the traction and deflection sheaves). The solution to accommodate bending would be: a rope construction with many thin wires; and to accommodate slippage: a rope with relatively few, but thick wires.[5] Depending on which of the two forms of strain are considered more important, the rope or strand construction is selected, i.e., Warrington (12 outer wires per strand), instead of Seale (9 outer wires per strand). With the passage of time, traditions have developed which are typical for certain countries or elevator manufacturers.

In addition, there are limitations of diameters for some rope constructions. There is hardly a rope manufacturer who would be eager to produce 8 x 25 filler wire ropes with a diameter below 10mm (approximately 3/8") because of the very thin filler wires, whereas 6 x 19 Seale ropes with a diameter above 16 mm (5/8") are rather stiff.

In part, this explains the variety of ropes available. In addition, the whole range of different elevators cannot be equipped with one type of rope and be expected to operate at an optimal level. Consider the financial aspects of using high performance ropes for slow-moving, seldom-used elevators. All the rope constructions shown in Figure 18 are special ropes, i.e., each rope manufacturer producing, more or less exclusively, a special steel core rope with only slight changes among competitor's rope design.

Number of Strands and Shape of the Groove

In traction calculations, the rope cross section is normally shown as follows: Figure 22.[6]

In reality, ropes of 6, 8, or 9 strands in a wide undercut groove of 105° undercut angle are very different from this simplification, as can be seen from Figures 23-25. The drawings on the right show the rope's cross section rotated around its fixed center with respect to the left drawing.

These diagrams help explain the adverse effect of undercut angles of more than 100°.

Where to Use What Rope Construction?

The following list shows typical applications; it is, however, by no means complete (Table 3).

Previous experience might lead to the use of constructions mentioned for applications differing from those shown here.

The Compensating Ropes (Tail or Balance Ropes)

This rope application does not require the same diameter precision or tensile grade of hoist ropes. The only required condition is the total weight of compensating ropes be approximately the same as hoist ropes. Cable laid ropes, for example, can be used as non-tensioned compensating ropes (Figure 26).

If compensating ropes are tensioned, ropes of the same construction and diameter as the hoist ropes can be used, or alternatively, a smaller number of thicker ropes. Rope constructions with a higher number of wires in the strands can be considered here, i.e., fiber core 6 x 36 Warrington-Seale (Figure 27), which are not suitable for use as hoist ropes. Compensating ropes of larger diameter should not have a steel core, as the relatively low rope tension sometimes allows the rope to twist, which causes damage, while a fiber core rope will come to no harm.

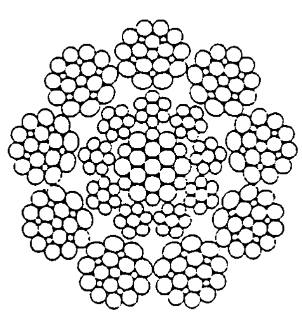

Figure 19: Rope cross section (Drako 300 T)

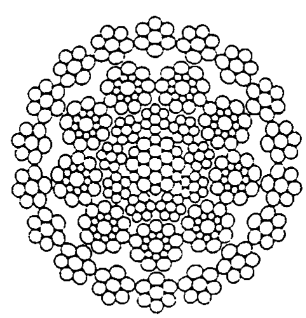

Figure 20: Rope cross section of a non-rotating rope (example)

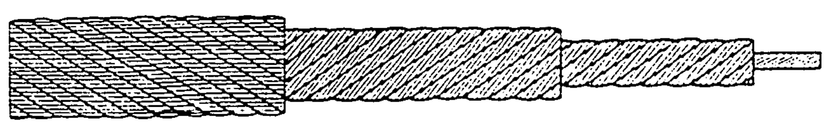

Figure 21: Directions of lay of the strand layers in a non-rotating rope (example)

Materials and Design of the Rope Core: Fiber Core

Natural fibers, sisal and hemp, are the most common materials for elevator rope cores. There are certain reservations about using polypropylene as the cheapest fiber material, at least for 8-strand ropes, which have relatively large fiber cores. As polyamide fibers are highly pressure resistant, they have been used successfully for the fiber core ropes in round grooves. They are, however, also relatively expensive. For governor ropes and compensating ropes in systems with long ropes, and in particular humid environments, man made fibers should be used. The reason is that natural fibers absorb moisture, the rope core swells and the rope becomes shorter. In the case of long governor ropes – too short! Table 4 shows some pros and cons of common fiber materials for use in the cores of elevator ropes.

For details of amount and purpose of lubricants in the fiber core, see the following section on relubrication in Part II.

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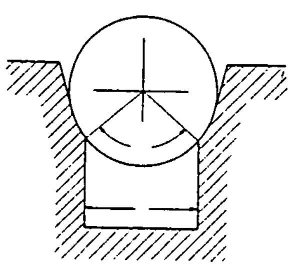

Figure 22: Fit of rope and traction sheave groove (rope cross section simplified as a circle)

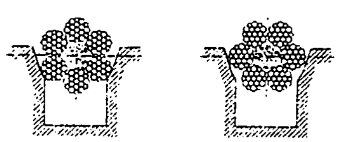

Figure 23: 6-strand rope in a U-groove with 105°

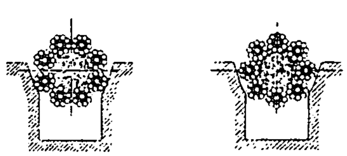

Figure 24: 8-strand rope in a U-groove with 105° undercut

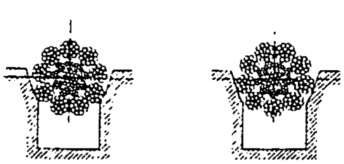

Figure 25: 9-strand rope with steel core in a U-groove with 105° undercut

Rope construction	Core	Common diameters mm	Proposal: to use as	Type of elevator installation	Lengths of single ropes in the installation m	Groove shape
6 x 19 Warr.	fiber	6 - 8 8 - 16	governor ropes hoist ropes	slow moving or seldom used elevators, goods elevators	up to approx. 50	all groove shapes unhardened and hardened, less suitable for wide undercuts
6 x 19 Seale	fiber	6 - 16	hoist ropes governor ropes			
6 x 25 Filler	fiber	13 - 16	hoist ropes compensation ropes			
6 x 26 Warr.-Seale	fiber	13 - 16	hoist ropes compensation ropes, tensioned			
8 x 19 Warr.	fiber	8 - 20	hoist ropes	all types of elevators included with double wrap	up to approx. 200	all groove shapes unhardened and hardened
8 x 19 Seale	fiber	8 - 20	hoist ropes			
8 x 21 Filler	fiber	13 - 22	hoist ropes (Canada)			
6 x 36 Warr.-Seale	fiber	20 - 36	compensation ropes, tensioned	any	any	
8 x 19 Seale 8 x 19 Warr.	steel and mixed cores consisting of wires and fibers	8 - 22	hoist ropes	general: frequently used systems with and without double wrap, particularly indirect hydraulic elevators high performance installation	any	all groove shapes particularly, round grooves and undercut U-grooves attention in hardened V-grooves
9 x 19 Seale*		8 - 9,5				
9 x 20 Filler*		10 - 13				
9 x 25 Filler*		14 - 22				
9 x 8		6 - 24				

Table 3

(*) Drako 300 T has a diameter dependent construction

Fiber material	Reasonable content of lubricant	Advantages	Disadvantages
Natural fiber: Sisal	- 17%	good absorption of lubricant, resistant to pressure, only small elastic stretch	sensitive to high humidity
Natural fiber: Hemp	- 22%	good absorption of lubricant, good strand bed, only small elastic stretch	less stable in diameter than sisal, sensitive to high humidity
Natural fiber: Jute	- 20%	—	only recommended for ropes with a diameter smaller than 6 mm
Manmade fiber: Polypropylene (split fiber)	- 12%	uniform in diameter	low resistance to pressure, can be plastified, will soften or melt at medium high temperatures
Manmade fiber: Polyamide	- 8%	highly stable under pressure, uniform in diameter	low absorption of lubricant, expensive, very elastic (difficulties in rope production), meltable
Manmade fiber: Aramid	not known, low	as fiber it has almost the tensile strength of steel, resistant to temperatures up to approx. 350°	the pure fiber too difficult to work into a traditional fiber core, very expensive

Table 4

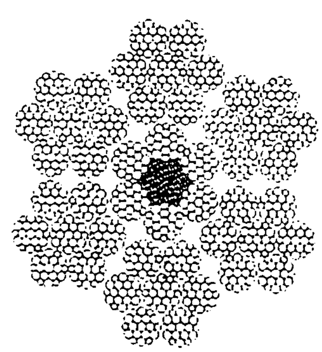

Figure 26: Rope cross section of a cable laid rope for use as nontensioned compensating rope

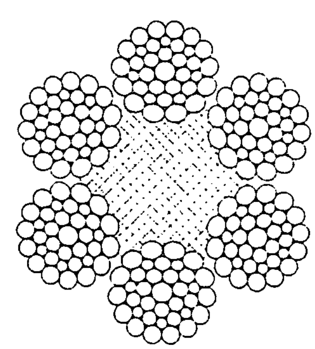

Figure 27: Rope cross section 6x36 Warrington-Seale + fiber core

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The Steel Core

As Figure 18 shows, steel cores can take varying forms. The steel core in Figure 19 is produced separately in an additional operation, whereas all strands in the rope in Figure 18 were closed in one operation. As explained in a previous section on parallel lay strands, the strands in this latter construction run in linear contact with one another (parallel closed ropes).

The one thing all ropes with a steel core have in common is they should not be allowed to open up during installation. Whereas the strands in a rope with fiber core all become longer or shorter to the same extent when the rope is twisted, the degrees to which the outer and the inner strands in a rope with a steel core will loosen are different. Special care is necessary when installing long ropes (over approximately 80m)l; if allowed to hang free in the shaft, they twist and open up due to their own weight.

The Lubrication of Strands and Core During Production

As the elevator rope is a running rope that is frequently bent over sheaves, it should be lubricated generously. Too much lubrication, on the other hand, will have a negative effect on traction. In addition, to make it more difficult to find the right amount of lubricant, the traction reserve in traction drive elevators can vary considerably, depending on the design. As elevator ropes are not usually produced specifically for one particular installation, the rope manufacturer has to consider the worst possible case, i.e., as a rule, a relatively low level of lubrication should be applied. A uniform quantity of lubricant in even distribution must be assured. It is far easier to re-lubricate a rope at a later date, as far as is suitable for the particular elevator concerned, than to degrease ropes which slip as a result of too much lubrication.

The lubricant applied in the initial lubrication process should not be so complex that there might later be problems with the chemical compatibility of the wide range of the lubricants in use for maintenance. Lubricants, which contain bitumen, are unsuitable, as stubborn crusts form on the sheaves and ropes. In special cases, i.e., where lubricants containing hydrocarbons cannot be used because of the presence of ozone in certain industrial facilities, there are synthetic but very expensive lubricants available.

Special Designs of Elevator Ropes: Right and Left Hand Lay

The normal elevator rope is a right hand lay rope, i.e., the outer strands form a right-handed helix (see Figure 28).

A practice that has now become extremely uncommon was to fit elevator systems with pairs of right and left hand (lay) ropes to reduce pressure on the guidings. A rope that is not rotation resistant, i.e., any elevator rope, will produce, as a result of its service load, a torque on its termination, and in the case of a 2:1 suspension, on the axle of the deflection sheave. If, in special cases, the counterweight really is unguided or only guided by wires, the solution is the installation of pairs of ropes of different lay directions. In all other cases, it should be remembered that the ropes in one installation should be as similar as possible, i.e., they should be cut from the same production run. Right and left hand ropes, however, are as different as possible, unless the very greatest care is taken. In winding drum elevators, the direction of the rope lay must be selected to fit the cut of the drum ("right hand rope – left hand drum").

Figure 28: Right hand lay rope ordinary lay

Figure 29: Right hand lay rope lang lay

Rope diameter mm	Rope diameter tolerances in %		
	new, unloaded	new, loaded with 5% of Minimum Breaking Load	new, loaded with 10% of Minimum Breaking Load
≤ 10	+ 6 + 2	+ 5 + 1	+ 4 0
>10	+ 5 + 2	+ 4 + 1	+ 3 0

Table 5

Preformed Ropes

Preforming or postforming a rope is a method to remove residual stress from the ropes by partwise plastification of the wires. When the seizing or serving at the rope end is removed, such a rope does not burst into a wild bundle of wires, but remains closed.

In the United States, there are sometimes still specific requests for nonpreformed elevator ropes. It is recognized as an advantage that, in addition to a smaller initial elongation of the rope, the ends of broken wires stick out for easier detection. The end of such a broken wire, however, will bend and soon damage other wires, unlike the broken end of a preformed wire. For this reason – and for installation reasons – usually only preformed elevator ropes are used in Europe. This has an effect on the standards for elevator ropes, where the preformed rope is the normal case.[6]

Prestretched Ropes

The main purpose of prestretching elevator ropes a certain amount permanently before installation is to reduce rope shortening after the elevator is in service.

Experienced elevator rope manufacturers have modified their closing machines to prestretch the ropes with approximately 30% of the rope's breaking force. Special prestretching equipment makes it possible to prestretch ropes to a higher extent (up to approximately 50% of the breaking force = heavy prestretching), but only as an additional process.

The 8-strand rope with a natural fiber core is the rope construction which can be prestretched most effectively. It is possible to achieve a permanent elongation of approximately 0.2%, as the strands are permanently embedded deeper in the big fiber core. In the case of ropes with steel cores, prestretching only has a relatively small effect on the permanent elongation of the rope. Rough handling during installation can cause the ropes to revert to their "normal" elongation. Ropes with a steel core should only be prestretched to reduce elongation if they are longer than approximately 100m. On the other hand, prestretching these ropes has the effect of equalizing the tension in the individual strands and wires, which is always an advantage.

Prestretching elevator ropes should be considered part of a cost-benefit analysis. There is no general rule as to which rope length, or for which type of installation, ropes should be prestretched.

Ordinary Lay and Lang Lay

Some years ago at a research institute in Stuttgart, fatigue bending tests were conducted and revealed that under certain conditions, lang lay ropes can break without warning from visible outer wire breaks (Figure 29).[7]

Consequently, the Deutsche Aufzug Ausschu* (DAA – German Elevator Committee) published limitations of application for lang lay ropes in elevators.[8] These results were, however, of only small importance to the German elevator industry, as ordinary lay ropes (see Figure 26) are generally used. The one exception in lang lay rope construction had already proved its suitability for elevator systems.

Lang lay rope is not considered to be a problem outside Germany. In England, for instance, users have the choice between lang lay and ordinary lay ropes with fiber cores. There is a tradition of using lang lay ropes for traction sheaves with U-grooves. In the United States, the use of lang lay ropes for certain traction drive sheave systems with plastic liners (see Part II) is preferred. But also with the common cast iron and steel traction sheaves, lang lay ropes are chosen by some elevator manufacturers. Advantages and disadvantages of the two types of rope lay are too numerous to mention here. However, two differences should be mentioned: lang lay ropes, especially those with a large fiber core, such as 8 x 19 + FC, open up to a greater extent than ordinary lay ropes when hanging free in a shaft. This calls for more installation care, particularly where longer ropes, i.e., over 40m, are being used. Unlike those in ordinary lay ropes, the wires in the strands of an opened up lang lay rope will loosen.

Note: A bad, or badly installed, lang lay rope is far worse than the worst ordinary lay rope; and elongation of a lang lay rope is noticeably higher than ordinary lay rope.

Tolerance of the Rope Diameter

Unlike crane ropes, elevator ropes for traction sheave installations with U-grooves must be produced with a reduced diameter tolerance.

In Germany, the following has been valid for new, unloaded elevator ropes; nominal diameter of the rope:

+0%
+3%.

As mentioned in a previous section on nominal tensile grade of wires, many elevator manufacturers have already worked ISO 4344 into their work standards. The tolerances for ropes, set by this standard, are shown in Table 5.[9]

Regarding the need of a very good rope to groove fit, these tolerances are still relatively high, and can only be valid for fiber core ropes.

Three reasons favor this:

- the fiber core, usually consisting of natural fibers, cannot be produced so exactly;
- the diameter of a rope with fiber core will decrease more rapidly once it goes into operation than that of a rope with a steel core; so for better service life, the rope, when newly installed, should at least be somewhat thicker; and
- if the rope is slightly too large for the round or undercut U-groove, a rope with fiber core will adapt and take on an oval shape.

Consequently, the ISO Standard 4344 only refers to elevator ropes with fiber core.[9] Ropes with steel core require a completely different range of tolerance. With luck, a European Standard for elevator ropes will soon clarify this point. The rules for such a range of tolerance can, however, already be logically defined: at the beginning, ropes like this must only be slightly thicker than the groove, otherwise their inability to change their shape to any great degree will lead to high pressure. Additionally, the elevator may possibly have too much traction.

For the last decade, the tolerance level for new ropes with steel core: nominal diameters

+2% unloaded,
-1% loaded (10% of the minimum breaking load),

have proven to be fine.

The rope tolerances for winding drum elevators could, in fact, be higher than those listed in ISO 4344.[9] On the other hand, this type of elevator is relatively uncommon; so it is a matter of economy to use normal elevator ropes, only with a higher level of lubrication.

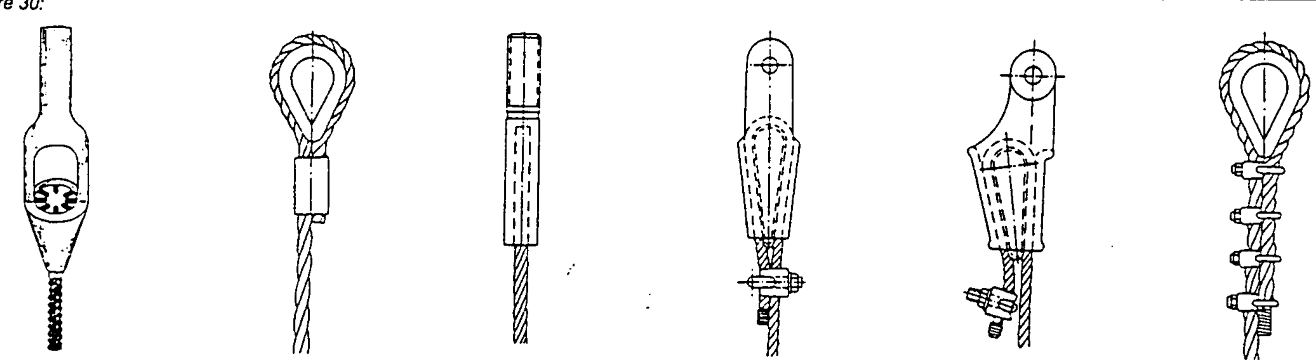
Rope Terminations

A number of different rope terminations are in common use in elevators (Figure 30).

All these terminations must be secured to prevent their twisting after installation. The individual terminations follow.

Continued overleaf

Figure 30:



Babbited socket — *Aluminium ferrule secured eye termination with thimble acc. DIN 3093* — *Steel terminal* — *Symmetrical wedge clamp acc. DIN 1533315 only for elevators* — *Asymmetrical wedge clamp acc. Draft DIN 3096* — *Wire rope grip secured eye termination with grips acc. DIN 1142*

Babbited Socket

While this method is dying out in Germany, it is still a common practice in other parts of the world. There, the experienced craftsman can complete such a socket in a very short time. The sockets used in elevators deviate greatly from ISO 3189 and are only safe to any degree in the elevator industry, with its traditional high rope safety factors.[10] The advantage of this termination is that it is very slim. It now seems possible to use resin instead of molten metal, i.e., the product "Wirelock", a material available all over the world.

The Eye Termination With Mechanical Splice

In elevator construction, this termination is usually combined with a thimble and an eye bolt. In Germany, terminations complying with DIN 3093 (aluminum ferrule secured eye) are very common, usually with a wedge clamp at the other end of the rope.[11] The mechanical splice must be done in the workshop, but this is not a problem in Germany, as virtually all elevator ropes are supplied to the elevator site cut to length and ready for installation. This termination is to be regarded as a very safe method, which makes it all the more regrettable that in the U.S., for example, the aluminum ferrule secured eye termination is treated with a certain degree of skepticism. Eye bolts used in connection with thimbles and ropes must have an extra large eye.

The Swaged Bolt-Terminal

The striking feature of this termination, also known as terminal, is its slim design. It is used in Austria and Switzerland; however, it has several disadvantages:

• the suitability of the material for the steel bolt must be checked carefully, because the wrong selection of steel quality can cause the bolt to burst lengthwise after pressing;

• if the compression is too high, as steel presses on steel, the rope inside the bolt can be partially squeezed off, whereas with the aluminum ferrule previously described, too much compacting pressure will cause only the aluminum to harmlessly flow away to the ends of the ferrule; and

• in fiber core ropes, which means most of the ropes used in elevators, the fiber core must be removed from the length of rope where the bolt is to be fitted and replaced with steel wire core; each rope is especially sensitive to vibration. Replacing fiber core in this way creates additional disturbance.

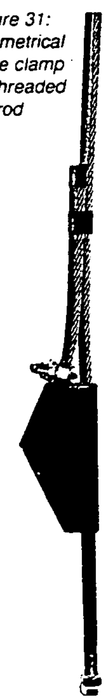
The Symmetrical Wedge Clamp for Elevators

This termination method is very widespread in Germany and England (DIN Standard 15315, BS 7166).[12, 13] Italy and Japan also use this special wedge clamp (Figure 30). Only wire rope grips conforming to DIN 1142 should be used to secure this termination.[13]

The Asymmetrical Wedge Clamp

The asymmetrical wedge clamp, i.e., conforming to DIN draft 3096 or BS 7166, Figure 30, is relatively bulky, and very often it is only possible to use it together with a series of eye bolts of different lengths.[15]

Figure 31: Asymmetrical wedge clamp with threaded rod



Care must be taken with slack ropes; in contrast to the symmetrical wedge clamp, the standards do not allow any strong rope grip around both the dead rope end and load-bearing part of the rope.

In U.S. elevator practice, this termination is secured against wedge-release at slack rope situations with small, non-rope-damaging grips, or simply with strong tape. Several elevator manufacturers have developed their own asymmetrical wedge clamp with threaded rod, all similar to Figure 31.

The Wire Rope Grip Secured Eye Termination

European elevator standard EN 81 permits fixing the rope end with "three suitable" wire rope grips. This aspect of the standard should be amended as soon as possible, as:

• in England, one of the countries with a widespread use of this type of termination for elevators, it is no longer permitted in new systems; and

• the wire rope grip, conforming to DIN 1142, generally considered to be highly suitable, provides at least four grips for rope diameters used by the elevator manufacturer.[14]

The foremost problem of fixing with wire rope grips is that grip screws have to be retightened from time to time. Additionally, it is anticipated that severe vibration of the rope will cause some hidden damage to the rope within the last grip.

When using wire rope grips, beware of laying lengths of rope on top of the car during rope shortening. If sections of rope where the wire rope grips had been positioned have to run over sheaves, the rope will more than likely break prematurely at these points.

The question of "Why Wire Ropes" will continue to be explored by Dr.-Ing. Molkow in Part II to be published next month. Readers are invited to ponder the issue and comment on the present state of the art, or perhaps become 2020 visionaries and suggest new techniques and approaches to elevator suspension. ... Editor

FOOTNOTES

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